

## THERMAL CONTROL SURFACES ON THE MSFC LDEF EXPERIMENTS

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## INTRODUCTION

There were five Marshall Space Flight Center (MSFC) experiments on the LDEF. Each of those experiments carried thermal control surfaces either as test samples or as operational surfaces. These materials experienced varying degrees of mechanical and optical damage.

Some materials were virtually unchanged by the extended exposure while others suffered extensive degradation. The synergistic effects due to the constituents of the space environment are evident in the diversity of these material changes. The sample complement for the MSFC experiments is described along with results of the continuing analyses efforts.

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## EXPERIMENT SURFACES EXHIBIT DIVERSE EFFECTS

The thermal control surfaces on the extended LDEF mission were exposed to a complex environment and experienced a wide range of effects due to this exposure.

### Optical/Thermal

- Spectral Reflectance/Solar Absorptance
- Thermal Emittance
- Fluorescence

### Physical

- Surface Roughening/Erosion
- Cracking/Peeling
- Weight Loss

### Chemical

- Surface Effects
- Bulk Effects

meig003

Figure 1. Effects of Space Environmental Exposure.

## MSFC LDEF EXPERIMENTS

Marshall Space Flight Center (MSFC) had five experiments on the LDEF that exposed thermal control surfaces to the space environment. All five experiments had materials that were exposed to the RAM orbital direction and the atomic oxygen environment. Two of the experiments also had samples on the LDEF trailing edge and saw very little atomic oxygen. The Thermal Control Surfaces Experiment (TCSE - S0069) performed optical measurements on orbit. AO114 and AO171 samples were half covered (protected) and half exposed to the environment.

	S0069	AO114	AO171	AO34	S1005
Exposure-Leading Edge	X	X	X	X	X
-Trailing Edge		X		X	
-LDEF Row #	9	3, 9	8	3, 9	10
In-space Optical Measurements	X				
Samples Half Exposed/ Half Protected		X	X		

Figure 2. Summary of MSFC Experiments.

# **THERMAL CONTROL SURFACES ON THE MSFC EXPERIMENTS**

The five MSFC experiments had a wide range of thermal control surfaces in their sample complement. Most samples were either low  $\alpha_S/\epsilon_T$  coatings or black paints. Protective coatings of RTV670 and OI650 were applied over Chemglaze A276 white paint and Z302 black paint to prevent erosion by atomic oxygen.

	S0069 TCSE	AO114	AO171 SAMPLE	A0034	S1005
A276 White	X	X	X	X	
A276/OI650	X				
A276/RTV670	X				
S13G/LO White	X	X	X	X	
Z93 White	X	X		X	
YB71 White	X			X	
White TEDLAR	X		X		
Silver TEFLON	X				X
Chromic Acid Anodize	X				
Z302 Black	X	X	X		
Z302/OI650	X				
Z302/RTV670	X				
Z306 Black		X	X	X	
D111 Black	X				
401-C10 Black			X		
Z853 Yellow			X		
Tiodize K17 Black			X		
Tiodize K17 White			X		

Note: Teflon and Tedlar are trademarks of Dupont.

Figure 3. Materials Complement on MSFC LDEF Experiments.

## THERMAL CONTROL SURFACES EMITTANCE CHANGES

The thermal emittance of most of the samples on the TCSE was essentially unchanged due to the extended LDEF exposure. The only exception was the 2 mil silver Teflon. Approximately 1 mil of this 2 mil Teflon material was eroded away by the incident atomic oxygen. The post-flight emittance of this material agrees well with laboratory measurements of 1 mil silver Teflon material.

<u>Material</u>	<u>Emittance ( <math>\epsilon_T</math> )</u>		$\Delta\epsilon_T$
	<u>Pre-flt</u>	<u>Post-flt</u>	
A276	.90	.93	.03
A276 w/RTV670	.91	.88	-.03
A276 w/OI650	.90	.89	-.01
Z93	.91	.92	.01
S13G-LO	.90	.89	-.01
YB71	.90	.89	-.01
YB71 over Z93	.85	.87	.02
Silver Teflon (2 mil)	.66	.46	.20
Silver Teflon (5 mil)	.81	.78	-.03
Silver Teflon (5 mil textured)	.82	.79	-.03
Chromic Acid Anodize	.84	.84	0

Idel200

Figure 4. Emittance Summary of TCSE Materials.

## A276 WHITE PAINT

Chemglaze A276 is a polyurethane white paint manufactured by the Lord Chemical Company. It was anticipated that this material would be eroded by the atomic oxygen environment so clear protective overcoatings of RTV670 and OI650 were applied to some of the TCSE samples. Figure 5 shows the change in solar absorptance of the A276 samples on the TCSE, A0114 and A0171. Note that the unprotected A276 on the LDEF leading edge experienced very little change in properties over the LDEF mission and in fact was somewhat whiter after the mission. A276 has been shown to degrade readily under solar UV exposure, much like the A0114 trailing edge sample and the clear overcoated TCSE samples. The AO erosion of the unprotected A276 on the LDEF leading edge removed the UV damaged material leaving an undamaged surface. Also notice that even though the major portion of the AO fluence occurred late in the LDEF mission, there was sufficient AO present in the early stages to prevent most of the UV damage.

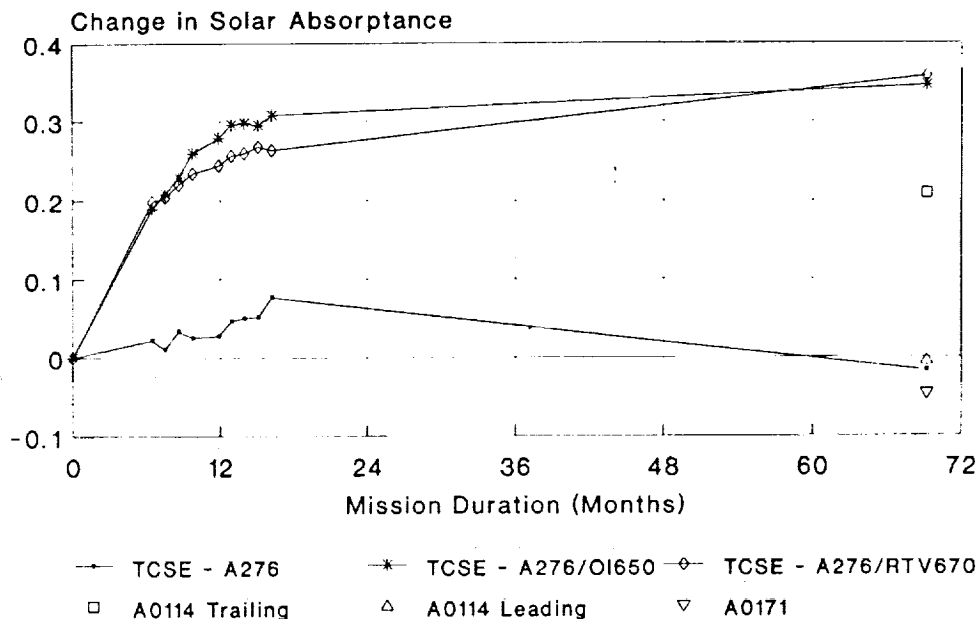


Figure 5. Performance of A276 White Paint.

## A276 REFLECTANCE DATA

The detailed reflectance data for the TCSE A276 samples shows the spectral changes in this material after 15 months and post-flight. The spectra shows that the samples continued to degrade after 15 months at some wavelengths while improving at others.

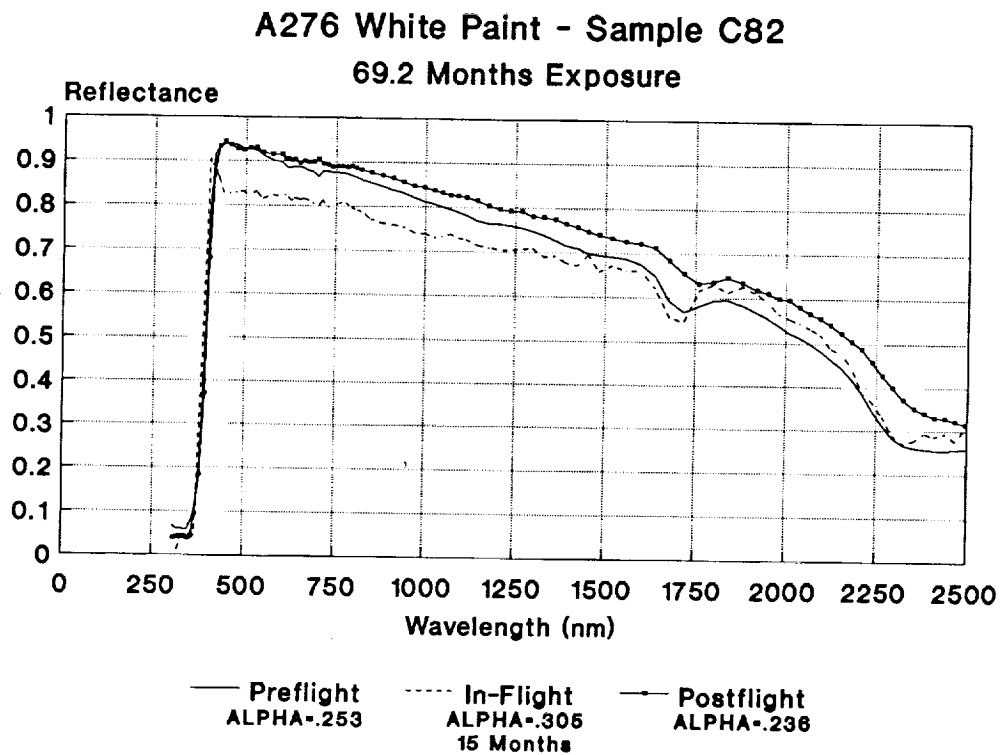


Figure 6. Reflectance Data for the TCSE A276.

**A276/RTV670 White Paint - Sample C88**  
69.2 Months Exposure

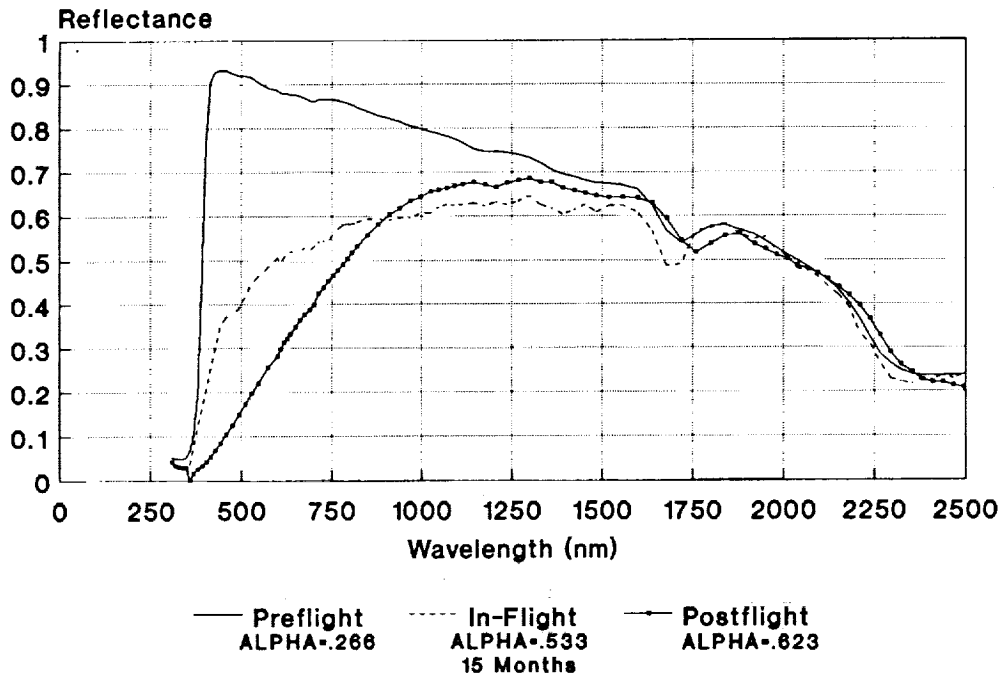


Figure 7. Reflectance Data for the TCSE A276/RTV670 Sample.

**A276/OI650 White Paint - Sample C87**  
69.2 Months Exposure

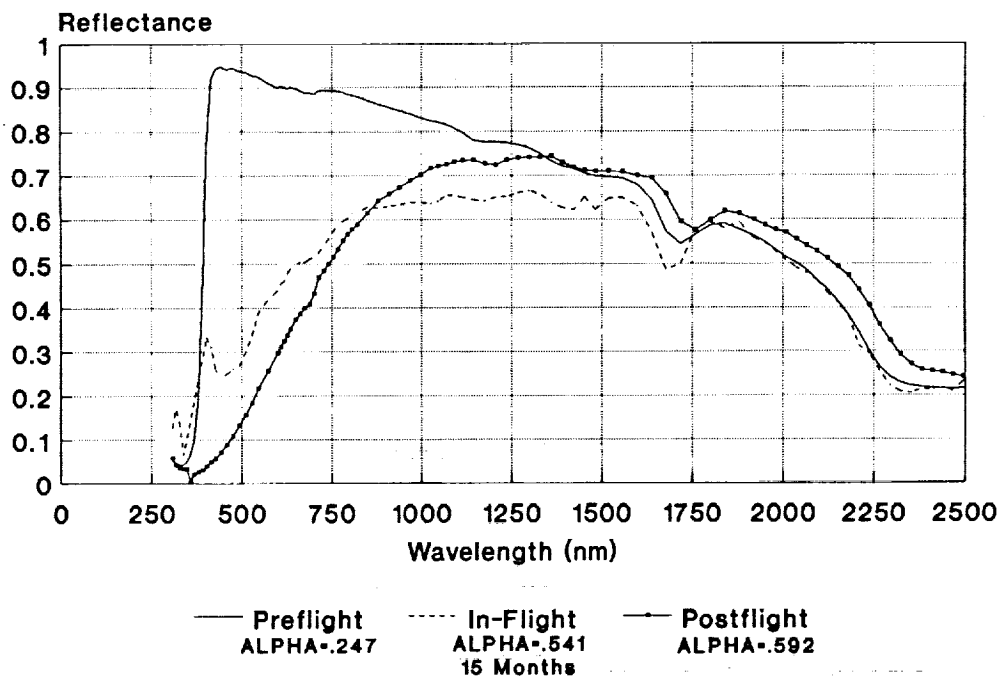


Figure 8. Reflectance Data for the TCSE A276/OI650 Sample.



## OVERCOATED A276 WHITE PAINT

While the clear protective coatings protected the A276 from AO erosion, they also caused cracking and peeling of the combined coating. These two photographs show the effects on the TCSE calorimeter samples. These samples were thermally isolated and saw wide temperature excursions. Other samples of these coatings were not thermally isolated and, while they did crack, they did not peel away from the substrate.

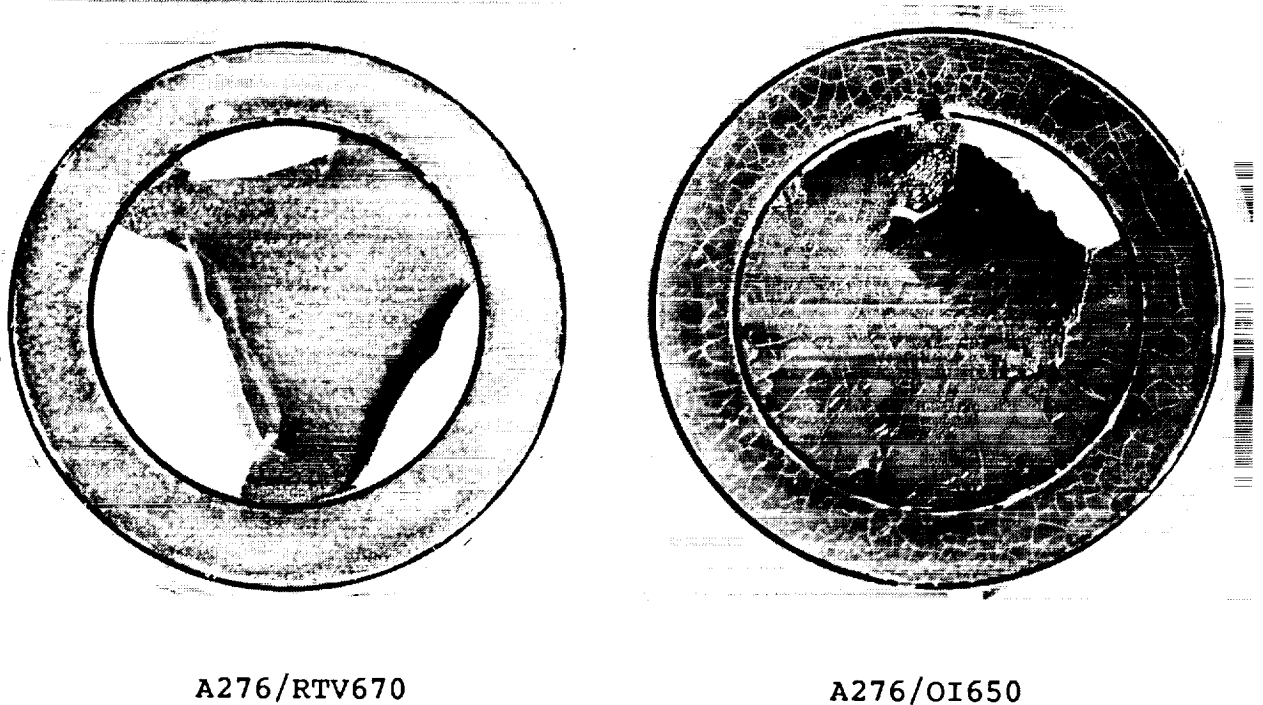


Figure 9. Photographs of Overcoated A276 Samples.

## Z93 WHITE PAINT

Z93 is a white paint from the IIT Research Institute and was very stable for the extended LDEF mission. A small improvement in solar absorptance occurred early in the mission which is typical of potassium silicate coatings like Z93. Only a small degradation was seen for the remainder of the mission. The solar absorptance of Z93 was also not effected by the AO environment as shown by the A0114 trailing edge sample.

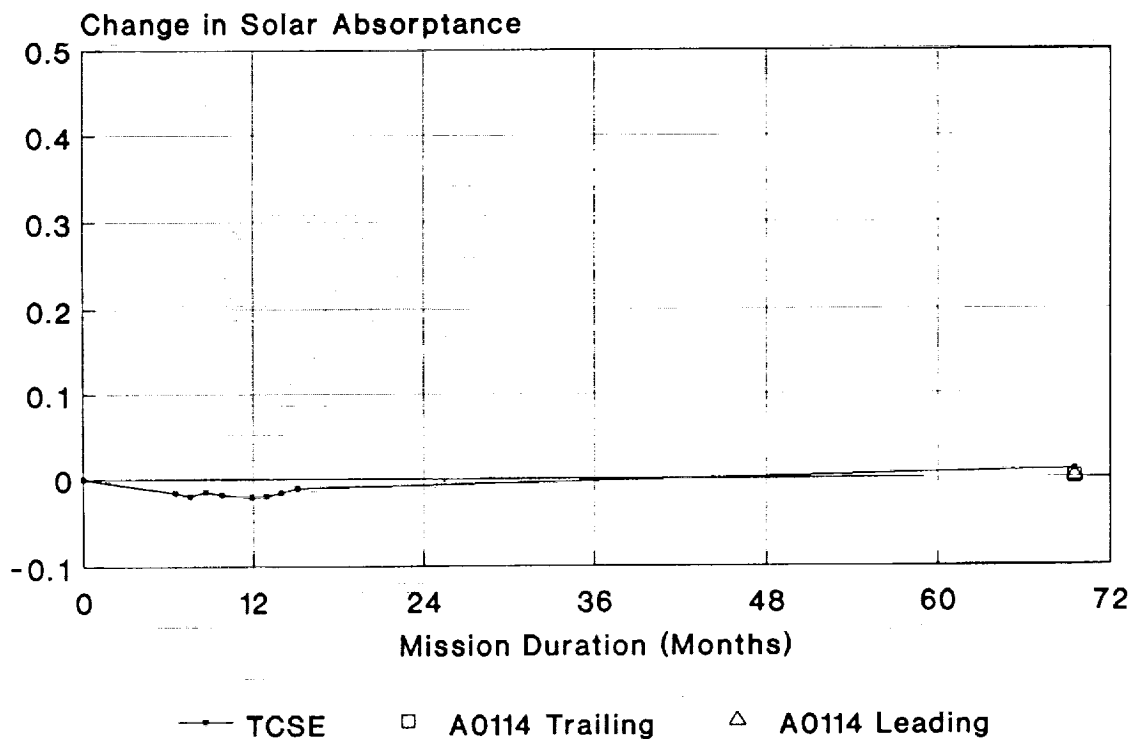


Figure 10. Performance of Z93 White Paint.

### Z93 REFLECTANCE DATA

The post-flight detailed reflectance data for the AO114 leading edge and trailing edge samples also show that Z93 was very stable for the extended LDEF exposure.

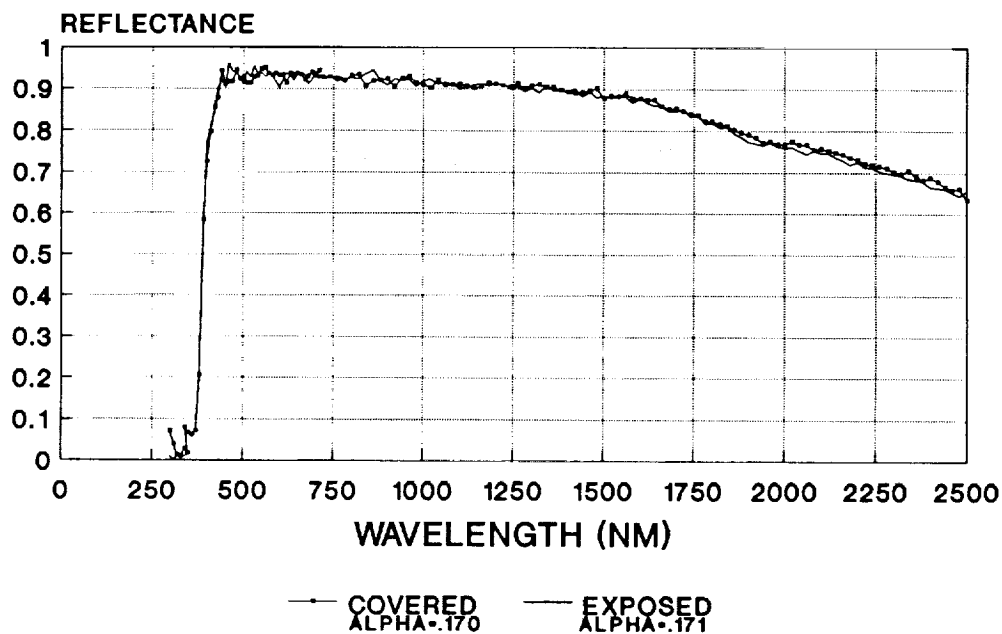


Figure 11. LDEF AO114 Z93 Trailing Edge Sample.

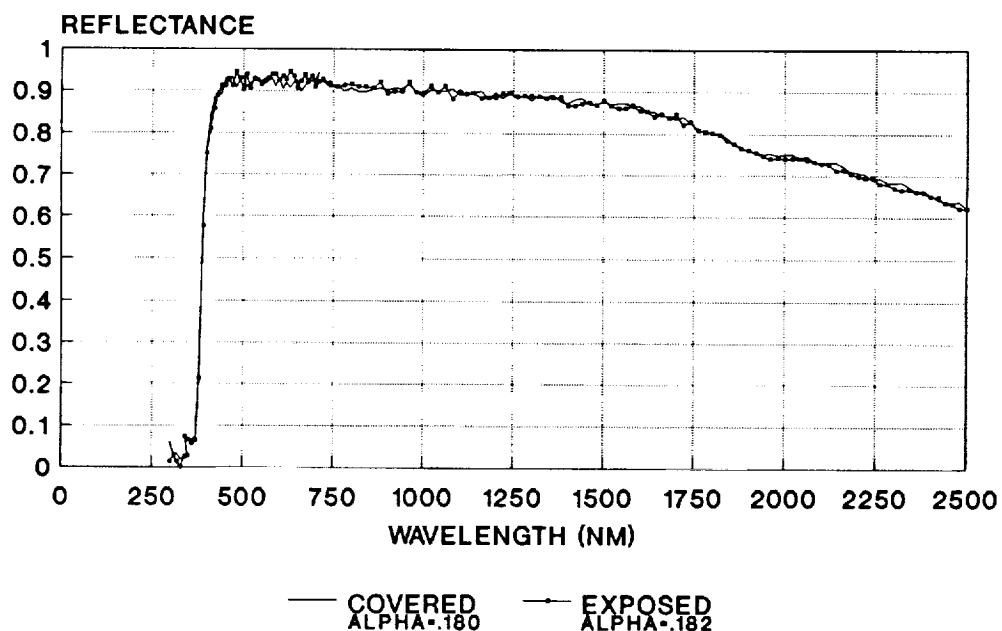


Figure 12. LDEF AO114 Samples Z93 Leading Edge Sample.

## S13G/LO WHITE PAINT

S13G/LO is also a white paint from the IIT Research Institute and has been widely used on space hardware. Ground testing predicted that S13G/LO would degrade moderately in the solar UV environment. This material did degrade on the LDEF mission but degraded somewhat more than expected on the TCSE. The variation in overall degradation of S13G/LO between the three experiments was unexpected and unexplained at this time.

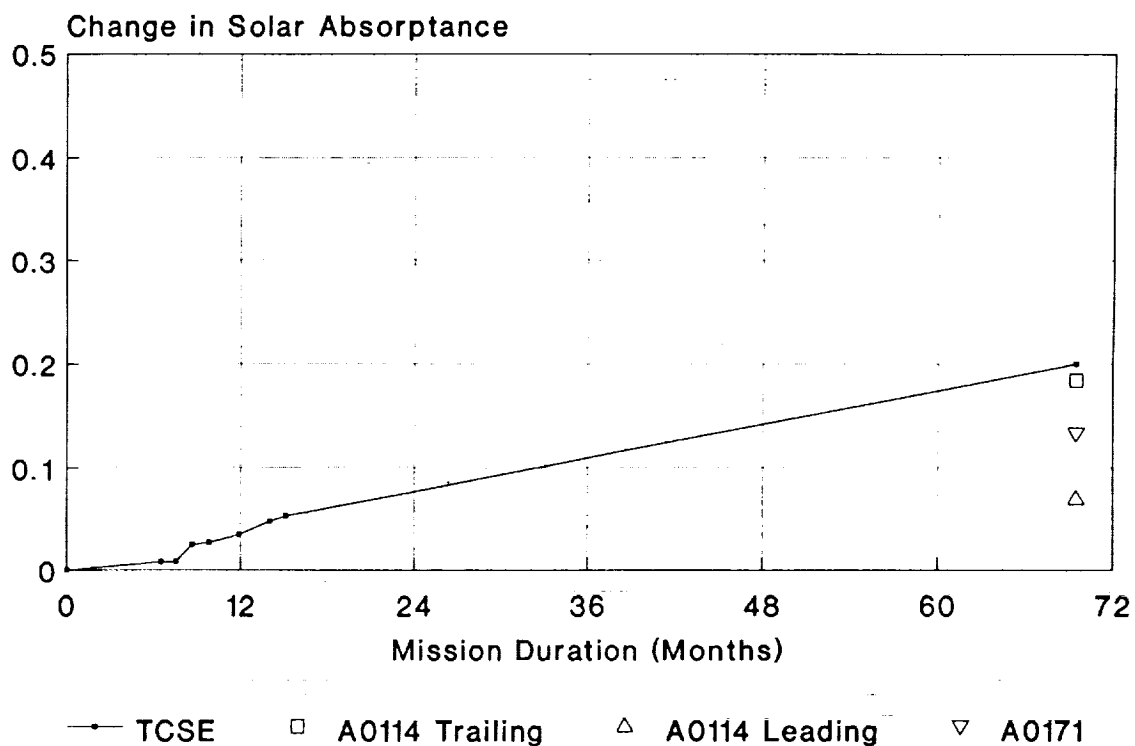


Figure 13. Performance of S13G/LO White Paint.

## S13G/LO REFLECTANCE DATA

The reflectance measurements of the TCSE and AO114 samples show how the material degraded spectrally. The spectral data of the samples from the two experiments do not explain the differences in degradation rates, however.

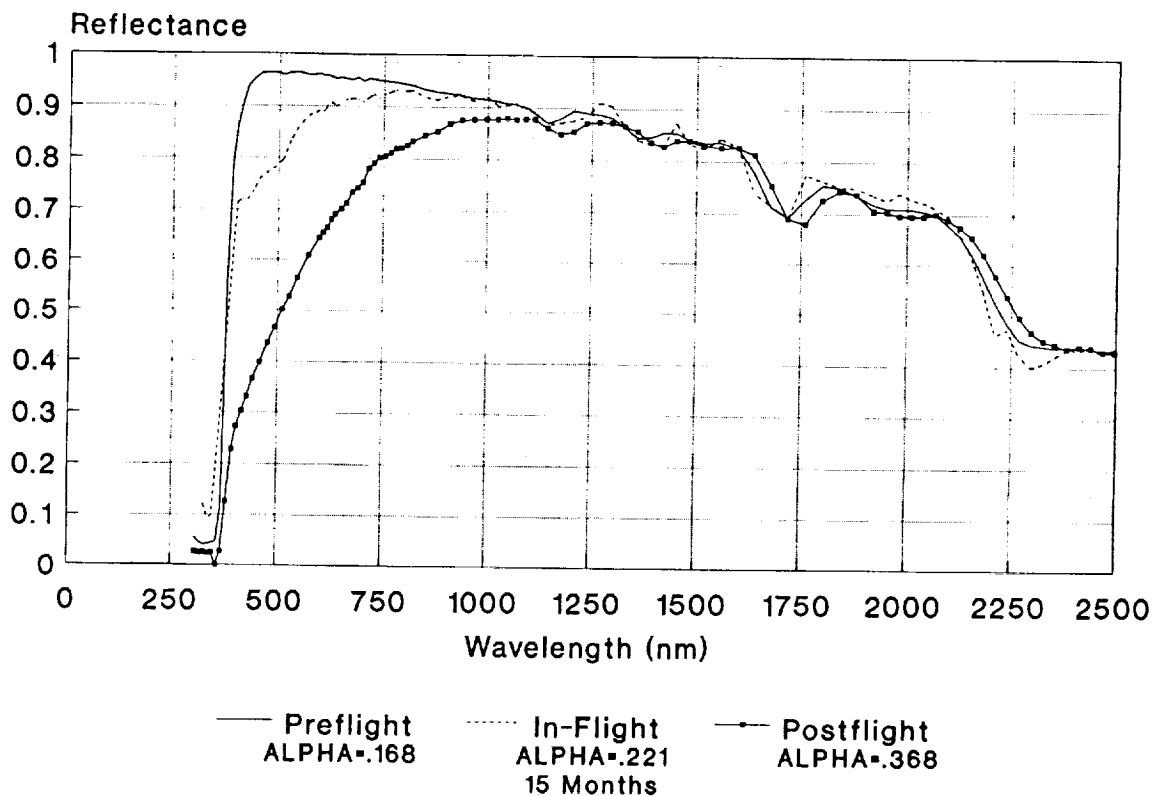


Figure 14. TCSE S13G/LO White Paint-Sample C92.

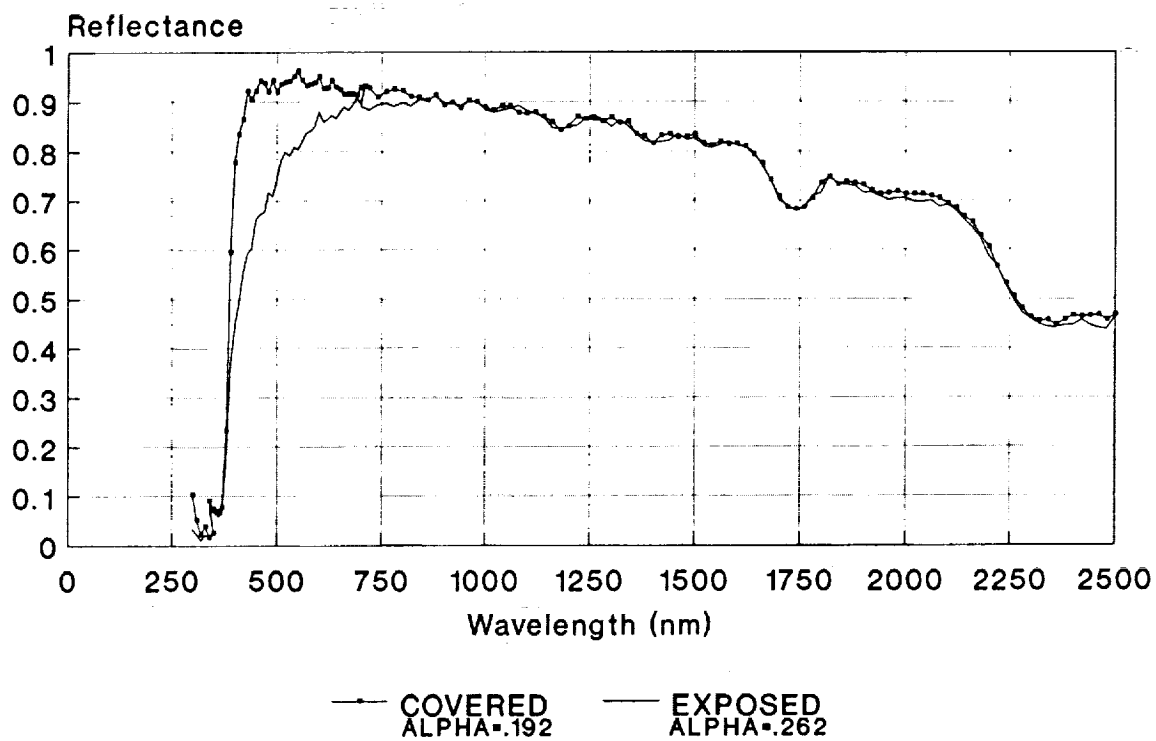


Figure 15. A0114 S13G/LO Leading Edge Sample.

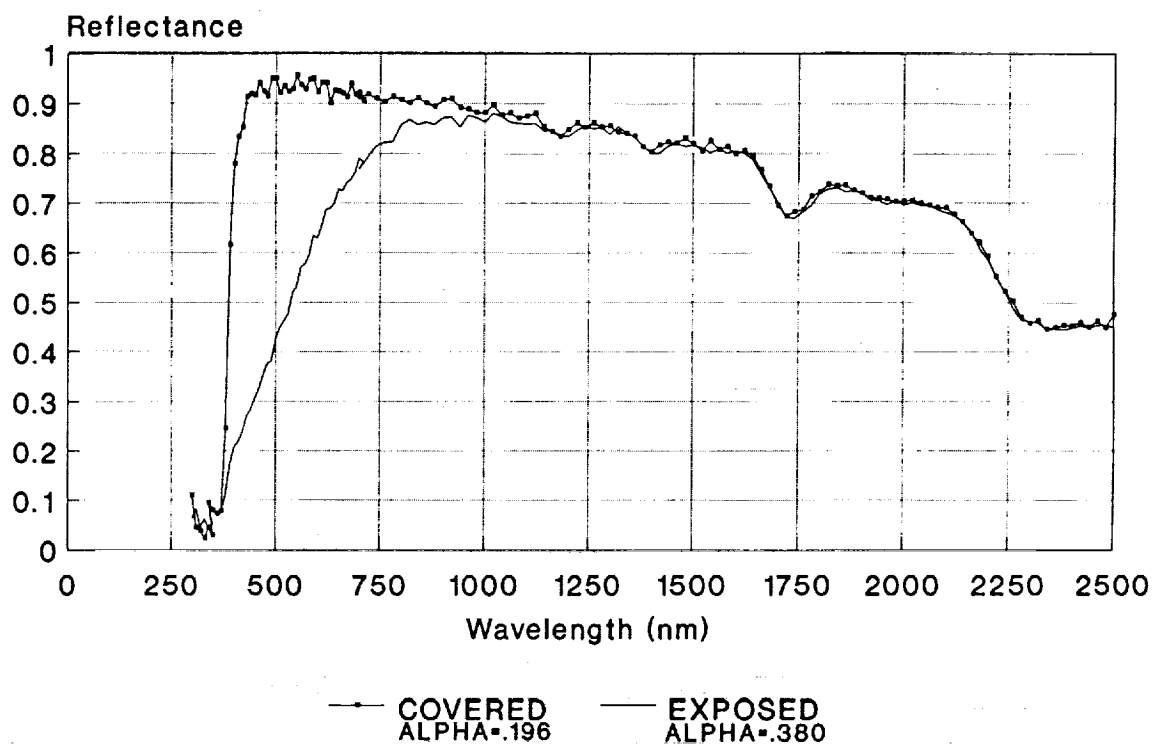


Figure 16. A0114 S13G/LO Trailing Edge Sample.

## SILVER TEFLON

Both 2 mil and 5 mil silver Teflon samples were flown on the TCSE. The 2 mil material was also used on the TCSE front cover for thermal control. Experiment S1005 used 5 mil silver Teflon for thermal control of the transverse heat pipes. All the Teflon surfaces were eroded by the AO environment and had the typical whitish appearance observed on other silver Teflon surfaces exposed to the RAM AO environment. The 5 mil material applied with a P223 adhesive was optically very stable for the LSEF mission. The silver Teflon applied with the Y966 adhesive showed a wide variation in post-flight measurements between test samples and measurement positions on the TCSE cover.

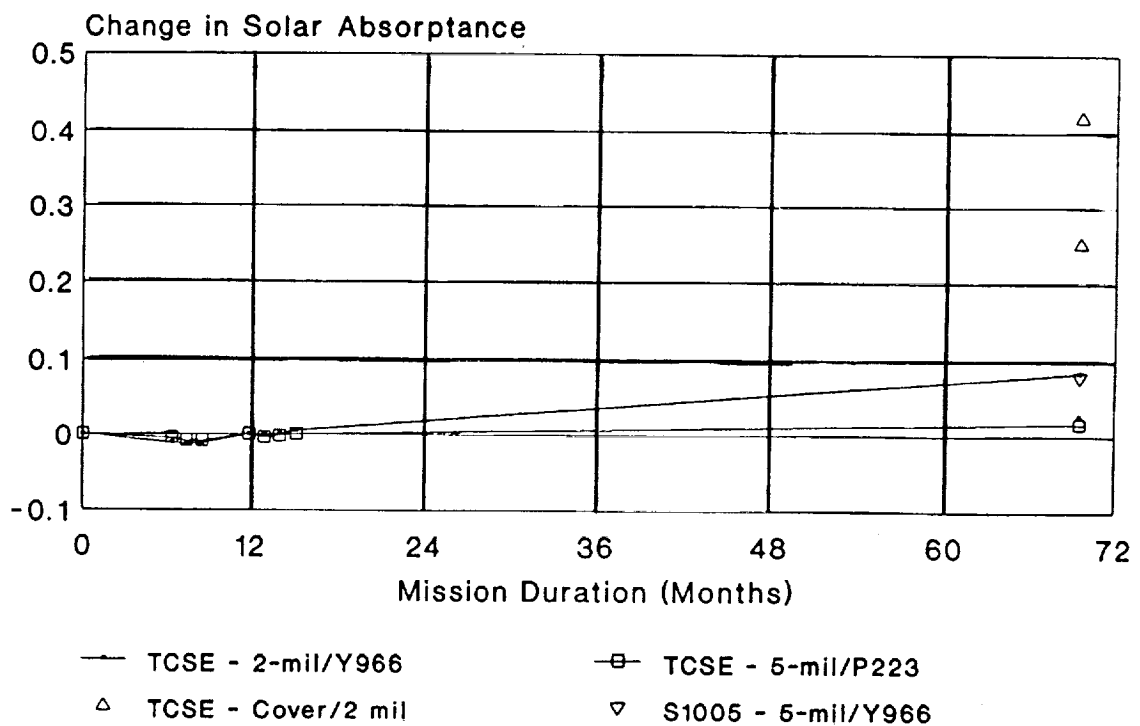


Figure 17. Performance of Silver Teflon.

## TCSE FRONT COVER DEGRADATION

The front cover of the TCSE was covered with 2 mil silver Teflon and suffered significant degradation. This photograph shows the front cover. This cover is aluminum with the pre-adhesive silver Teflon film applied to it. The specular undamaged areas on the left and right sides and in the middle were protected by secondary covers. The streaky discoloration was caused by a cracking of the silver/inconel backing on the Teflon and the subsequent migration of components of the Y966 adhesive through the cracks into the silver and Teflon interface. This contaminant was then degraded to a dark brown by solar UV exposure. This cracking was caused by the application of the pre-adhesived silver Teflon including the removal of the paper backing and the working of the surface to remove air bubbles.



Figure 18. TCSE Front Cover.



## SILVER TEFLON REFLECTANCE DATA

Samples were cut from several locations on the TCSE front cover and measured in the laboratory. These locations were selected to demonstrate the wide variation in surface degradation.

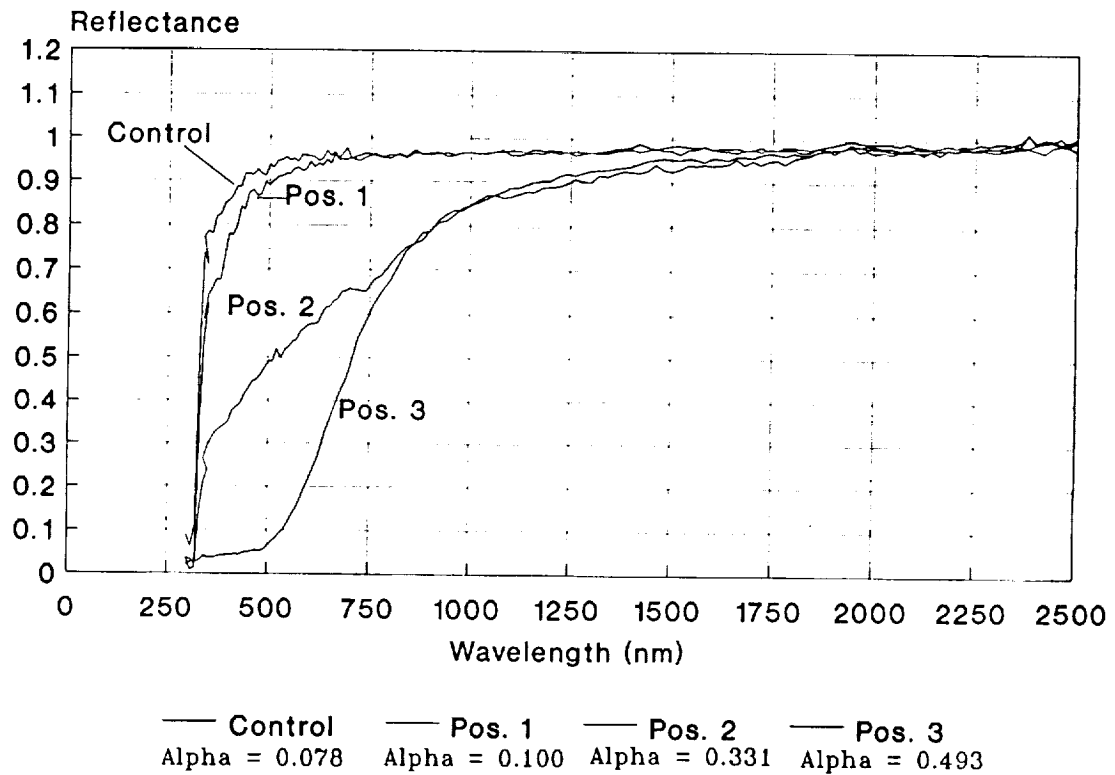


Figure 19. Measurements at Selected Locations on the Front Cover.

## CHROMIC ACID ANODIZE

Two chromic acid anodize samples were provided by Wayne Slomp (LaRC) and were flown on the TCSE. One of the samples was exposed for the complete LDEF mission while the other was directly exposed for only the first 19.5 months of the LDEF mission. As can be seen from the data in Figures 20, 21, and 22 the two samples tracked well during the early stages of the mission as is shown by the TCSE in-flight measurements. The exposed sample, however, improved optically during the subsequent four years of exposure. This sample (69.2 month exposure) appears washed out and mottled while the other sample (19.5 month exposure) has an even coloring.

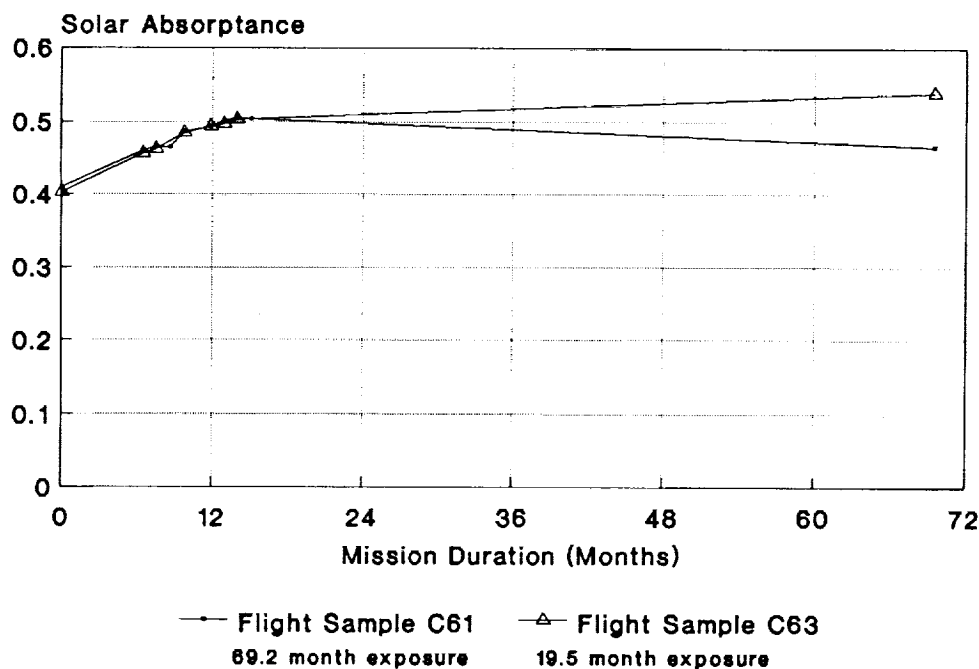


Figure 20. Performance of Chromic Acid Anodize.

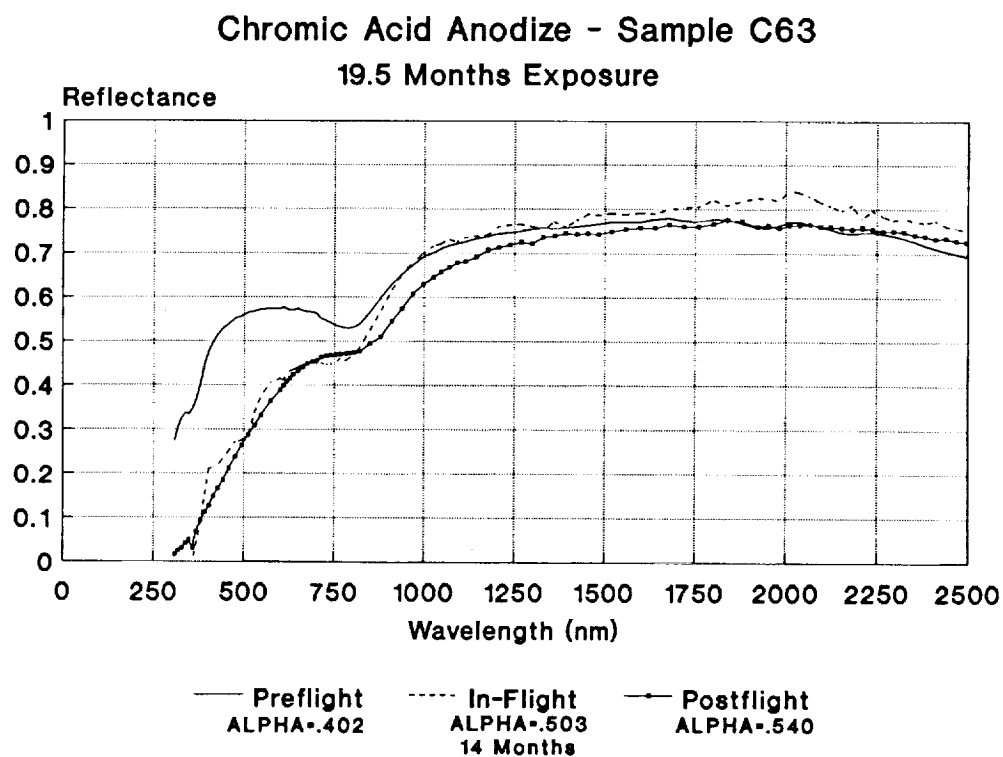


Figure 21. Reflectance Data for Chromic Acid Anodize.

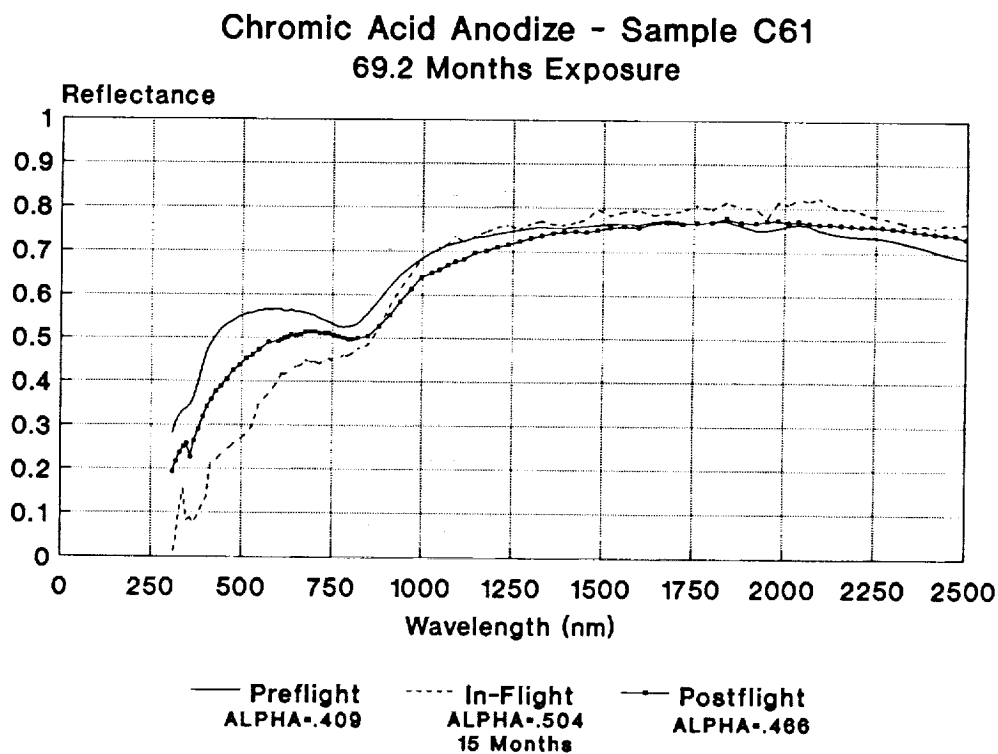


Figure 22. Reflectance Data for Chromic Acid Anodize.

## YB71 WHITE PAINT

YB71 is another inorganic white paint from the IIT Research Institute. This YB71 sample was applied over a primer coat of Z93. As with Z93, YB71 was very stable for the extended LDEF exposure. This material exhibited a small initial improvement in reflectance (and solar absorptance) followed by a very low degradation rate.

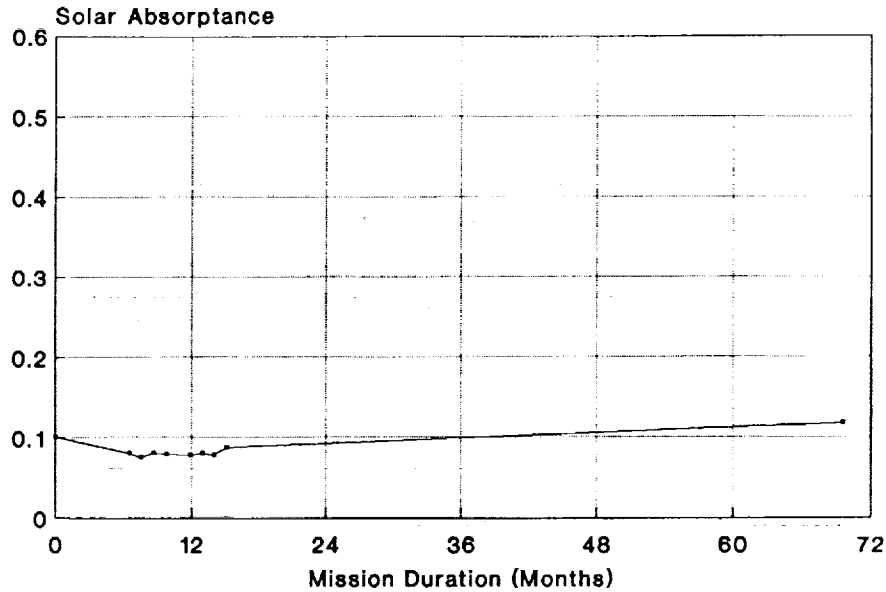


Figure 23. Reflectance Data for YB71 White Paint.

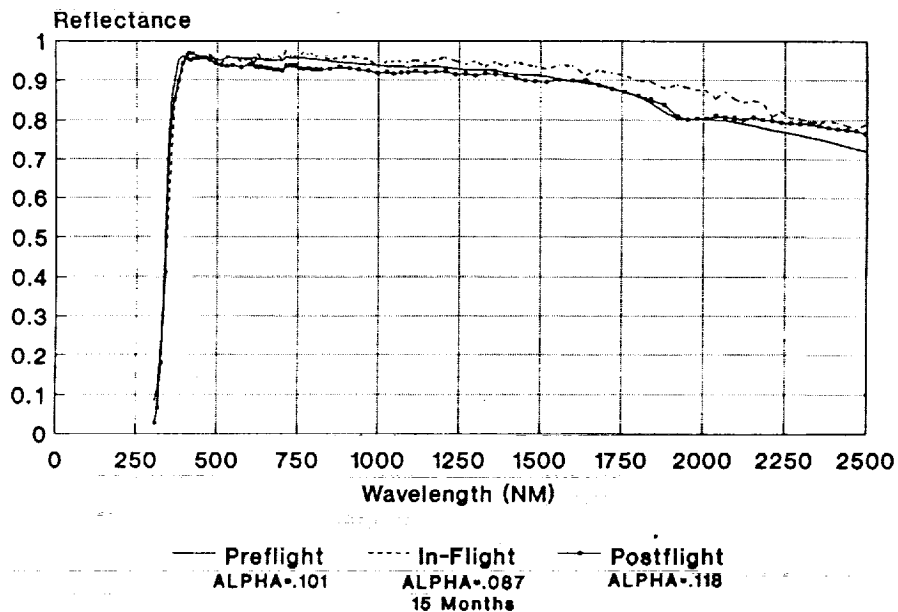


Figure 24. Performance of YB71 White Paint.

## WHITE TEDLAR FILM

White Tedlar is another material that was expected to degrade over the 5.8 year LDEF mission due to solar UV exposure. Instead, the reflectance properties of this material improved slightly, as shown in Figures 25 and 26. The surface remained diffuse and white, similar to pre-flight observations. As with A276, Tedlar has been shown to be susceptible to AO erosion. The erosion effect of AO is the apparent reason for the lack of optical degradation of these flight samples.

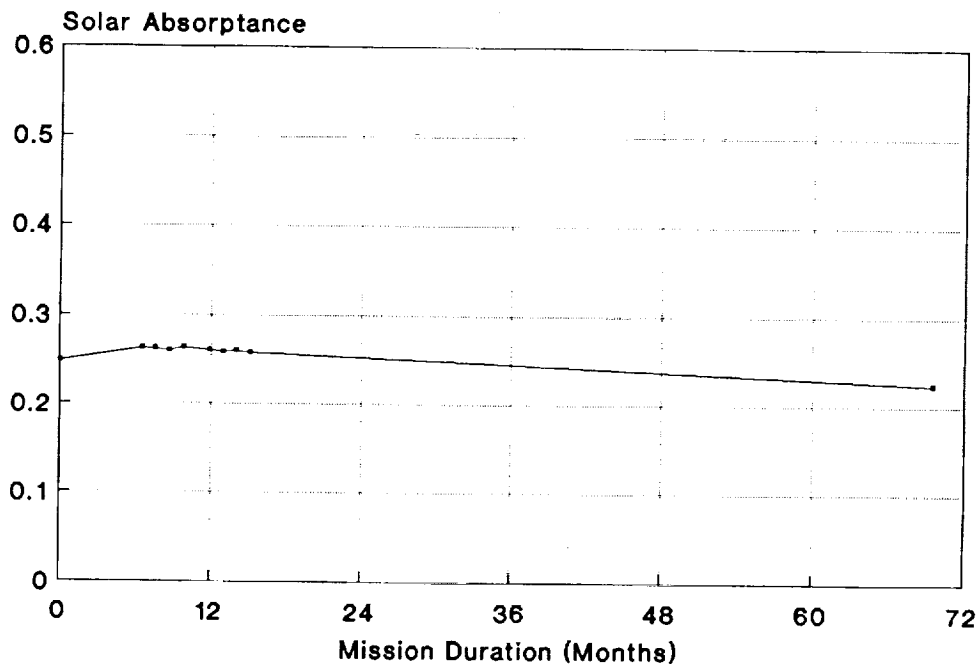


Figure 25. Reflectance Data for White Tedlar.

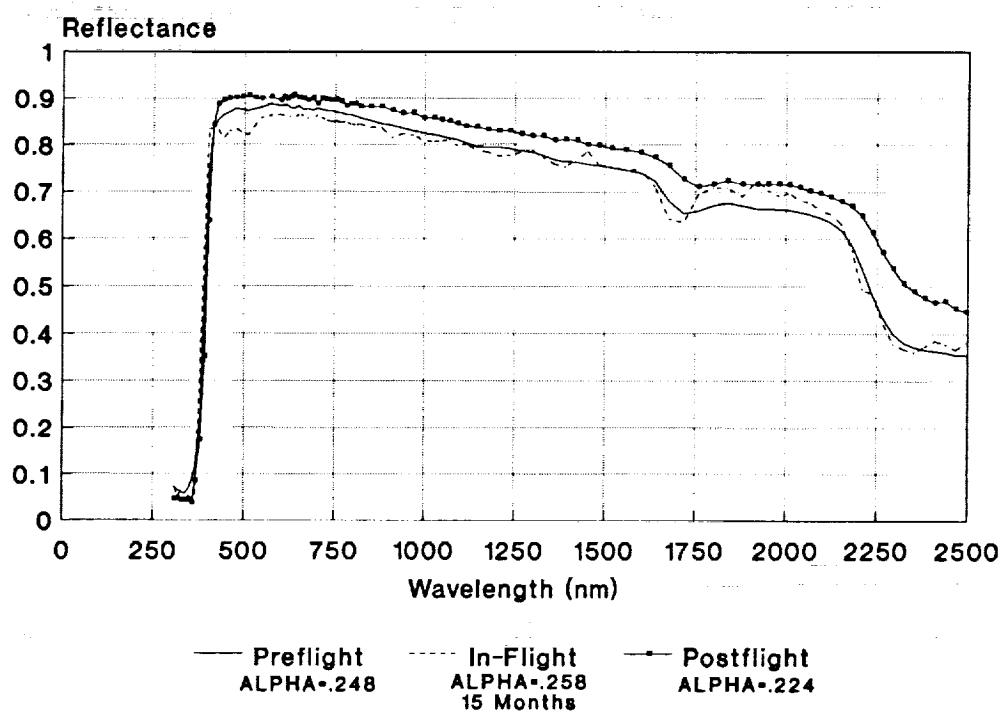


Figure 26. Performance of White Tedlar Film.

## SUMMARY

The LDEF mission provided an excellent test bed for the behavior of materials in the space environment. The thermal control surfaces on the MSFC experiments experienced many types of mechanical and optical changes due to the LDEF space exposure. Some materials such as Z93 and YB71 were very stable for the extended exposure. Many other materials were significantly degraded both mechanically and optically. Some materials such as A276 and Tedlar were relatively stable optically but were significantly eroded by the AO environment. Silver Teflon was also eroded by AO but was optically stable where properly applied. The most significant problem with the silver Teflon was where the silver/inconel layers were cracked during the application of the pre-adhesived material. This problem points out the significance of the preparation and application process for long term stability of materials in the space environment.

With the diversity and complexity of the materials effects due to the extended LDEF mission, there remains many analyses to be performed to fully realize the benefits of the LDEF.

